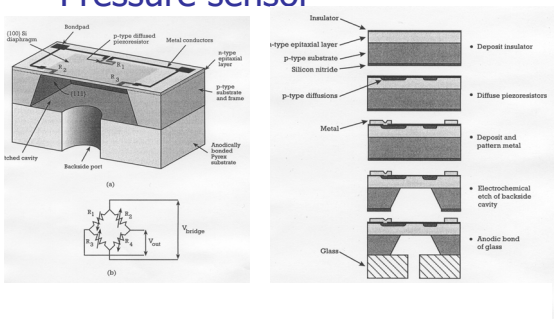
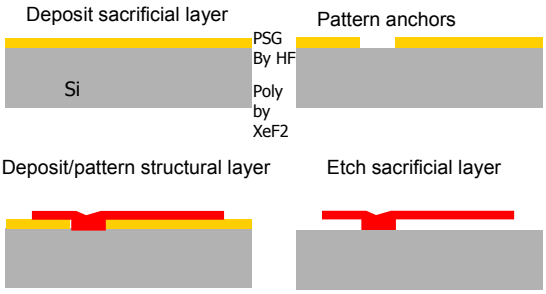
Pressure sensor



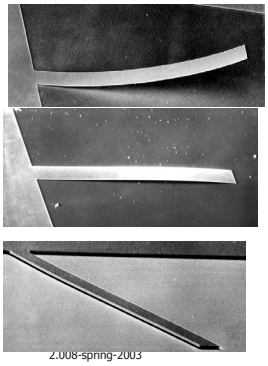
Surface Micromachining



Surface micromachining

Structure	sacrificial	etchant
Polysilicon	Silicon dioxide	HF
SiNx	PSG	HF
Silicon dioxide	polysilicon	XeF2
SiNx	polysilicon	XeF2
Aluminum	photoresist	oxygen plasma

Residual stress gradients



More tensile on top

More compressive on top

Just right!

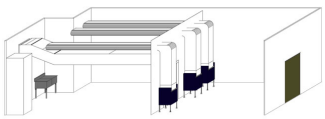
Clean Room

- Gowning with bunny suit
- Class 1, 10, 100

A salt grain on a chip

Class of clean rooms

- Class 1 means one speckle of 0.5 μ partical in one ft^3.
- Class 10, 100, 1000
- HEPA filter, AHU



Air Filters

- HEPA (High Efficiency Particulate Air) filters
- High efficiency, low Δp, good loading characteristics
- Glass fibers in a paper like medium
- 97% retainment of incident particles of 0.3 μm or larger

Class of clean rooms

Class	0.5 μ particle	Temp tolerance	RH tolerance	$/ft^2
10,000	10,000	+/- 3ºF	+/- 5%	$250-300
1,000	1,000	+/- 2ºF	+/- 5%	$350-400
100	100	+/- 1ºF	+/- 5%	$1200
10	10	+/- 0.5ºF	+/- 3%	$3500
1	1	+/- 0.3ºF	+/- 2%	$10,000

Particles

class	0.1μ	0.2μ	0.3μ	0.5μ	5.0μ
1	35	7.5	3	1	N/A
10	350	75	30	10	N/A
100	N/A	750	300	100	N/A
1000	N/A	N/A	N/A	1000	7

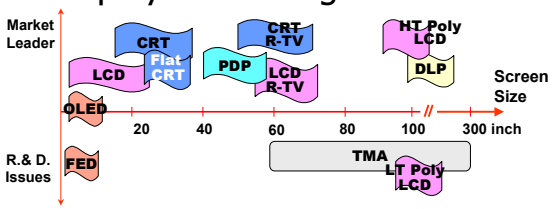
Federal Standard 209; Number of particles per cubic foot

Toxicity

- TLV (Threshold Limit Value)
  - Upper limit material concentration that an average healthy person can be exposed without adverse effects, ppm or mg/m^3
- Notorious Poisons
  - CO (100 ppm), CO_2 (5000 ppm), HCN (110 ppm), H_2S (10 ppm)
  - SO_2 (5 ppm), NH_3 (50 ppm)
  - Arsenic trioxide AS_2O_3 (0.1g fatal)
  - Hg (0.1 ppm via skin contact)
  - All material are toxic in sufficient quantity, 5g caffein is fatal.

MEMS Applications

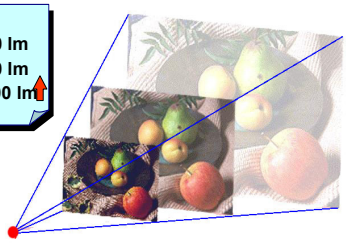
Display Technologies



- HDTV for 60" ~ 80" Home Theater
- Digital Presentation for 100 " ~ 300" Projector
- Key Factor : Brightness

Brightness of Projection Displays

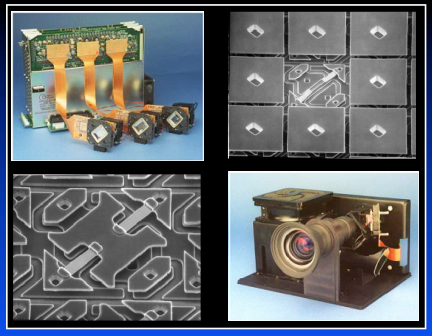
1995
CRT : ~300 lm
LCD : ~600 lm
? : ~2000 lm



lux = lumen / m²

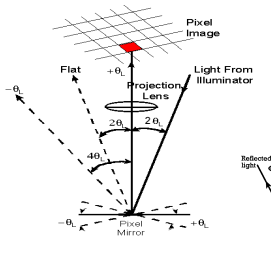
TEXAS INSTRUMENTS **1st Optical MEMS device** PHOTONICS AND MICROMACHINING

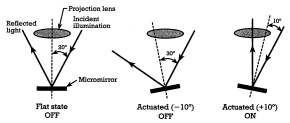
DIGITAL MICROMIRROR DEVICE & DLP™ PROJECTOR



04365-39 CORPORATE RESEARCH & DEVELOPMENT

DMD Optical Switching Principle

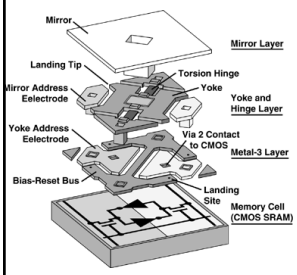


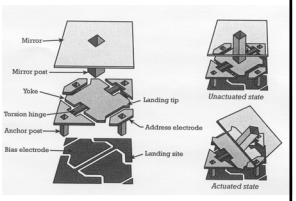


DMD Mirror on/off ± 10°

Texas Instruments's Technical Journal: Vol. 15, No. 3, July-Sept. 1998.

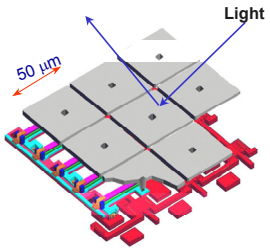
DMD Cell Structure





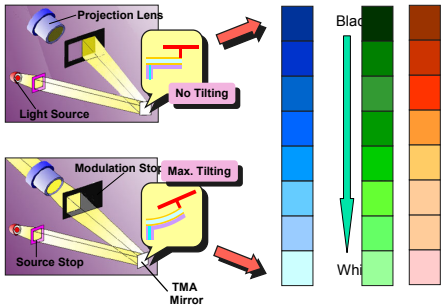
Texas Instruments's Technical Journal: Vol. 15, No. 3, July-Sept. 1998.

TMA

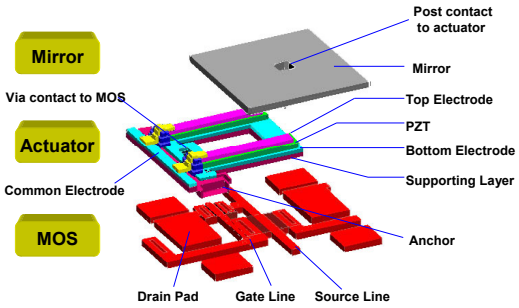


Light Modulation of TMA

Thinfilm Micromirror Array



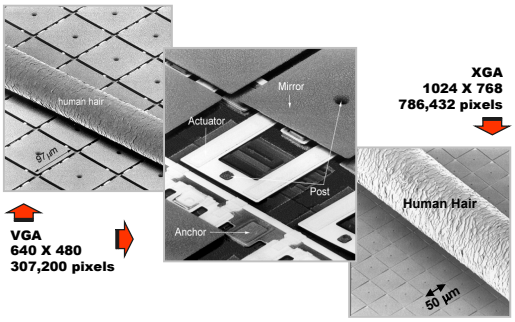
Pixel Architecture



TMA vs DMD

	DMD™ (Texas Instrument) Electrostatic	TMA™ (Daewoo Electronics) Piezoelectric
Actuation		
Tilting Angle	-10°, 0°, +10°	0° ~ 3° (continuous)
Gray Scale Control	On/Off Complex	Linear Simple
Drawbacks	• Fatigue • Sticking • High Cost	• Uniformity

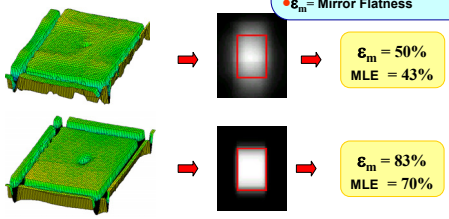
Micromirror Arrays



Mirror Flatness (VGA)

$MLE = \varepsilon_f \times \varepsilon_r \times \varepsilon_m$
$= 0.81 \times \varepsilon_m$

- MLE = Module Light Efficiency
- ε_f = Fill Factor = 90%
- ε_r = Reflectvity = 90%
- ε_m = Mirror Flatness

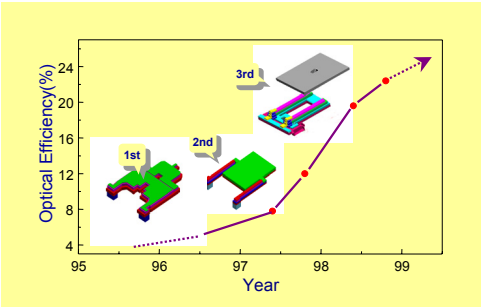


(97μm × 97μm TMA mirror)

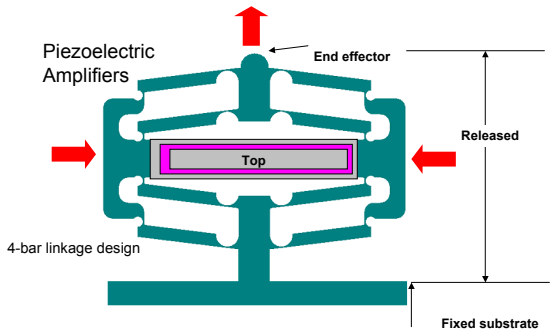
Coupled Natures of Thin Film Processes

- Forward coupling
  - Step coverage, confromality
- Backward coupling
  - Temperature dependent microstructural degradation
  - Over/under etch, etch stop control
  - Side attack, Passivation breakage

Evolution of TMA Pixels

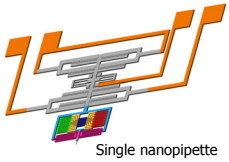


MIT Bow-actuator Nick Conway, MS 2003



Design of nanopipette (2): In-line array of nanopipettes

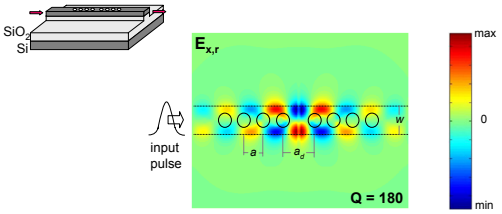
- Massive Parallel Nanopipette Array by In-plane Scanning Probe Systems
- Integration with Microfluidic channels
- Integration of nanopipettes in AFM in an 100 x 100 array



Single nanopipette

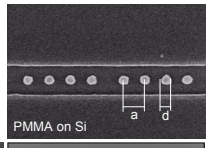
Photonic crystal modeling

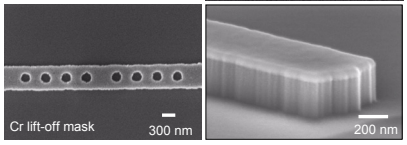
Microcavity waveguide finite-difference time-domain [1] mesh



Photonic band gap microcavity waveguide processing

- design matrix of various geometries: defect lengths, waveguide width, d/a, number of holes
- Nanofabrication:
  - SiN_x mask[1] /w electron-beam
  - Proximity pattern transfer to resist
  - 130 nm minimum features
  - Hard mask from Cr lift-off [2]
  - Optimized Si RIE

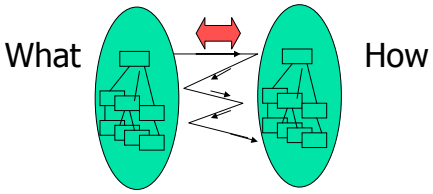




[1] J. Ferrera, NanoStructures Laboratory, MIT. [2] J. Foresi, Kimerling group, MIT.

Design Domains

- Design is a mapping process
- From "What" to "How"
- Small scale systems design



N. P. Suh, Axiomatic Design, Oxford